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South Indian Cardamoms And Their Agricultural Value

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PRINTED IN INDIA BY THE MANAGER, GOVT. OF INDIA PRESS
NASIK ROAD, PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI
1958

Price: *Rs.* 3·00 *or* 5*sh.*

EDITOR : U. N. CHATTERJI

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INTRODUCTION

A careful study of the useful economic characters, the natural distribution and relationships of the different types of a crop plant, both cultivated and wild, is of utmost importance in any programme of work formulated for its improvement by selection, breeding and agronomic practices. It is mainly with this object in view that in connection with any comprehensive scheme of crop improvement a type collection is made, grown side by side under identical conditions at an experimental station and studied. Accordingly, the items of work, *viz.* survey of the cardamom growing tracts of South India, study of the ecological distribution and morphological differences of the existing varieties and types in their natural habitats and the study of their botanical and economic or agricultural characteristics when grown together, were included in the programme of the I.C.A.R. Scheme for Scientific Aid to Cardamom Industry in South India, worked at the Cardamom Research Station, Singampatti Hills, Madras State. This paper, presented in two parts embodies the results of such studies carried out at the Cardamom Research Station, during the period 1942 to 1954.

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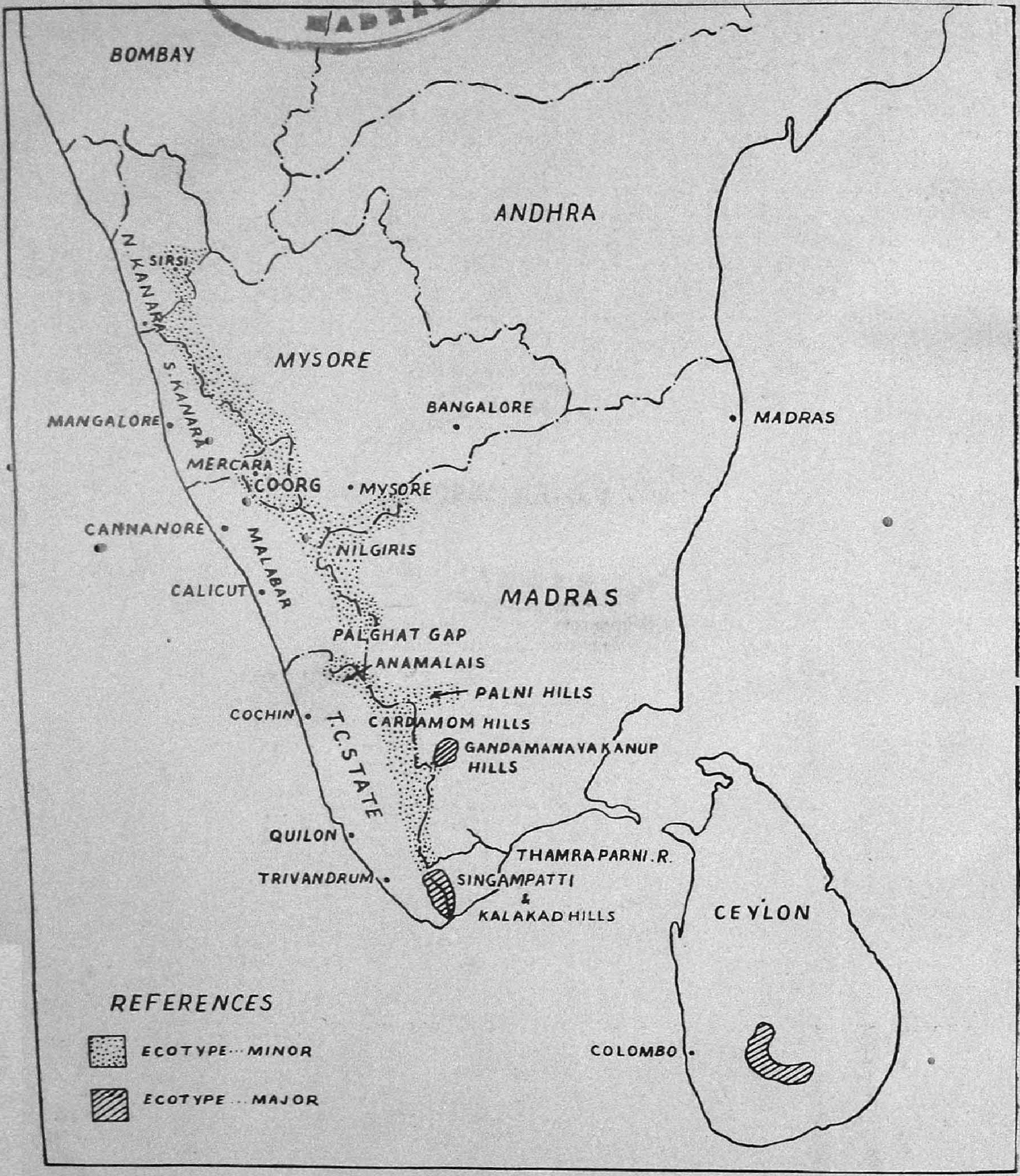

Map of South India showing the distribution of ecogeographical races of cardamom

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PART I

SOUTH INDIAN CARDAMOMS, THEIR EVOLUTION AND NATURAL RELATIONSHIPS

INDIA with the exception of Ceylon, wherefrom there is some export, still holds a monopoly with regard to the export of cardamom, a very valuable spice. According to Flückiger and Hanbury (1879) "the first writer who definitely and correctly states the country of cardamom appears to be the Portuguese navigator Barbosa (1514) who frequently names it as a product of the Malabar Coast". According to Redgrove (1933) "Gratia de Orto (1563) seems to have been the first European to have made a first hand study of the spice in India ; and he refers to a large form less aromatic than the Indian as being produced in Ceylon". The generic name *Elettaria* originated from Maton (1810-11) who segregated the Malabar cardamom, then known as *Amomum cardamomum* L, from *Amomum* as a distinct genus *Elettaria*. The scientific name *Elettaria* was derived by Maton (1810-11) from the local (Malayalam) name "Elathari". For purposes of clarity the taxonomic history of the genus is presented in Table I.

TABLE I

Taxonomic History of Genus Elettaria

S.No.	Author	Year	Classification	Remarks
1	Maton	1810-11	Segregated the Malabar cardamom then known as *Amomum cardamomum* L. from *Amomum* and named it *Elettaria* as a distinct genus.	
2	Thwaites, G.H.K.	1861-64	The larger kind of cardamom mentioned by Gratia de Orto (1563) as having been produced in Ceylon was named as *E. cardamomum* Maton, var. *major*.	
3	Baker (in Hooker)	1894	Mentioned *E. cardamomum* Maton, as grown in South India and mentions of a single variety E. *Cardamomum* Maton var. *major* Thw.	This variety has been described as a robust plant with leaves broader than the type and having oblong, fusiform fruits one inch or more long and indigenous in Ceylon. Further, mention is made that the species has leaves that are pubescent beneath; bracts two to seven flowered; seeds not arillate. The detailed description by Baker (in Hooker) is given after this table.
4	Schumann, K.	1904	Revised *Zingiberaceae* as a whole. In this work two species of *Elettaria* are recognised namely *E. cardamomum* L. Maton and *E. major* sm. corresponding to *E. cardamomum* Maton var. *major* Thw.	Schumann's description follows rather closely that of Baker in Hooker, except the fact that he recognised two species.

S. No	Author	Year	Classification	Remarks
5	Fischer, C.E.C.	1928	Agreed with the classification of *Elettaria* by Baker (in Hooker 1894).	
6	Molegode, W.	1938	This author mentions three varieties of *Elettaria cardamomum* Maton, as found in Ceylon, one of which is indigenous to that island. The cultivated varieties 'Malabar' and 'Mysore' appeared to have been introduced from India.	The Malabar variety is described:— Leaves silky on the under surface; racemes arise from the base of the stem and creep on the surface of the ground around the clumps; fruits or capsules angled, shorter and more globular than the Mysore type. The Mysore variety is described :— Leaves larger with a coarser under surface, not silky but hard and smooth; racemes rise erect, fruits oblong and larger than those of the Malabar type.
7	Narasimhaswamy, R.L.	1940	The author mentions three varieties of cultivated cardamoms then in existence in Mysore. They are :—1 var. *major* Thw. mentioned by Baker (in Hooker 1894) and Fischer (1928); 2. var. *Mysorensis* corresponding with the Mysore cardamoms of Molegode (1938); 3. var. *laxiflora* which appeared to the author to have been not described previously.	This author mentions that the species *Elettaria cardamomum* Maton has leaves that are either glabrous or pubescent beneath; flowers are produced in 2 to 12 flowered short racemes in the panicles, seeds are arillate. He describes the varieties as follows :— (1) var. *major*. Having 6 to 40 flowered short racemes in the panicle and fruits that are 0.5″ to 0·8″ long. (2) var. *Mysorensis*, differing from *Mysorensis* of Molegode (1938) in having leaves that are glabrous or pubescent beneath and panicles that are erect or decumbent. (3) var. *laxiflora* with glabrous leaves, lax decumbent panicles having 4 to 40 flowered short, lax racemes that have flowers with long pedicels and fruits which are elongated.

The description of the genus *Elettaria* by Baker (in Hooker) is as given below :

Elettaria Maton. Rootstock thick, horizontal, perennial. Leafy stem long. Leaves oblong-lanceolate. Panicle produced direct from the rootstock, long, flexuous, decumbent, bracts 2-3-fed; flowers shortly pedicelled, bracteolate. Calyx cylindric, membranous, shortly lobed. Corolla-tube cylindric ; mid-segment oblong, convex, lateral narrower. Lateral staminodes minute teeth ; lip obovate-cuneate ; filament very short ; anther-cells contiguous, not crested. Ovary 3-celled ; ovules many, style filiform, stigma small ; turbinate. Capsule globose or oblong, coriaceous, indehiscent. Seeds small, angled by pressure.

E. cardamomum, Maton in trans. Linn. Soc. x.254; Bentl. & Trim. Med. Pl. t. 267; Thw. Enum. 318; Horan. Prodr. 30. Alpinia cardamomum, Roxb. in Asiat. Res. xi.355. Hort. Beng. l; Coromand Pl. t.226; Fl. Ind.i.70; Grah. Cat. Pl. Bomb. 206.; Dalz & Gibs. Flor. Suppl. 86. Amomum cardamomum, Linn. Sp. 1; White in Trans. Linn. Soc. x.220 t.4-5. A repens. Willd. Spl. Plant.i.9; Woddv. Med. Bot. t.131. A. racemosum, Lam. Encyc.i.135 Cardamomum officianale. Salisb. in Trans. Linn. Soc.i.232—Rheede Hort. Mal. xi.9, t. 4-5

Malabar. On the Western Ghats, from Kurg southwards (wild or cultivated). *CEYLON* (cult).

Leafy stem 6-9 ft. leaves 1-2 ft. by 3 in., pubescent beneath. Panicles several to one leafy stem, 1-2 ft; bracts linear-oblong, persistent, 1½-2 in. Calyx ½ in. Lip longer than corolla-tube shortly exserted; segments ½ in. Lip longer than the corolla-segments, white sheathed with violet. Capsule subglobose or oblong, marked with many fine vertical ribs.

Var. major. Thw. Enum. 318; more robust, leaves broader, capsule 1 in. oblong-fusiform. E. major, Smith in Rees. Cyclop; Horan. Prodr. 31—*Ceylon*, up to 3000 ft. (indigenous).

Since then Mayne's (1942) brilliant report on cardamom cultivation in South India was published. The general observations recorded by him on the various cultivated types and some wild forms of cardamoms he came across in the different cardamom growing regions of South India are highly illuminating. Based on his observations on the outstanding botanical features, habitat and distribution of South Indian cardamoms, he was of the view that "the clearest primary division of types appears to be that based on size and vigour. The smaller type, the leafy shoots of which, rarely exceed 10 ft. is also characterised by prostrate panicles. This is the Malabar cardamom". He found the Malabar cardamom cultivated in Mysore, Coorg, Cardamom Hills of Travancore and wild in the Anamalais and considers the cultivated type of North Kanara also to belong to this group. Mayne (1942) did not attempt a systematic classification of the genus, probably because of his realisation of the unsatisfactory nature of classical taxonomic methods in dealing with cardamoms. After extensive surveys and studies of cardamoms under cultivation and in the wild state in the principal cardamom tracts of South India, the present authors came to the conclusion that cardamoms offer exceptionally satisfactory material for the application of the "experimental" method of taxonomy according to the more modern conceptions of ecological differentiation and evolutionary taxonomy. Such an attempt is modestly made in Part I of this paper.

Material and Method

The climatic, environmental, soil and other conditions under which cardamoms are cultivated and wild cardamoms grow were studied by extensive surveys of cardamoms under cultivation and in wild state, in the principal cardamom growing tracts of South India. The surveys began with the starting of the Research Station in the Singampatti Hills, in 1944 and went on year by year until 1953. The following cardamom growing areas were surveyed during the period :

1. *Tirunelveli District*

Singampatti Hills	(Plantations and forests)
Papanasam Hills	(Plantations and forests)
Courtallam and Sivasailam Hills	(Plantations and forests)
Sivagiri Hills	(Plantations and forests)

2. *Madura district—Lower Pulneys*

Pattiveeranpatti Thandigudi Kumili Poopalankodai area	(Plantations and surrounding forests)

3. *Travancore State—Cardamom Hills*

Peermade/Devicolam taluks

4. *Coimbatore District*
The Anamalais (Plantations and surrounding forests)

5. *Nilgiris District*
Ouchterlony valley

6. *Malabar District*
Wynaad

7. *Coorg*
Sampage, Madanad and Bagamantla

8. *Mysore*
Kadur and Hassan Districts

9. *South Kanara*
Panathady and Chermadi

The different types of cardamoms grown in these hill tracts were examined in their habitats with respect to their natural and ecological distribution and morphological characters. The cardamoms naturally growing wild in the forests of these tracts were also sought for and observations on botanical characteristics and ecological distribution recorded.

Seeds of specimens of the different types of cardamoms found in these tracts were collected for trials at the Cardamom Research Station. While collecting types, care was taken to include in the collections very productive plants representing the types. The following were the types collected for comparative study at the research Station.

1. Singampatti Ceylon (Ceylon type grown at Singampatti group of estates)
*2. Singampatti indigenous
3. Anamalais—flexuous type
4. Anamalais—erect type
5. Munzerabad type from Mysore (found to be of the larger type with flexuous panicles)
6. Pattiveeranpatti type
7. Anamalais—prostrate type

8 and 9 Bodinayakanur—2 types (III and IV)
(indigenous types of the Cardamom Hills of Travancore)

Seedlings of all these types were raised in nurseries and planted out side by side as trial plots in 1948. The objects of these trials were not only to test the comparative yields of these types and their other useful economic features but also to study their morphological and habit differences when grown under identical conditions with a view to clarify their relationships.

The growth and development of these various cardamom types were under study year by year. The morphological and habit characteristics under study were:

1. Height of aerial shoots of full grown plants
2. Length and breadth of leaves
3. Petiole length
4. Pubescence of leaves
5. Habit of panicles (erect, flexuous or prostrate)
6. Leng th of panicles
7. Compactness of panicles
8. Nature of racemes and pedicles
9. Size, shape and colour of fruits
10. Flowering habits—periodicity
11. Size and structure of flowers
12. Productivity, *i.e.* yield
13. Oil content.

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*Note.—The indigenous nature of the substantial acreage under cardamom in the Singampatti area was established under the authority of the Management of the Singampatti Group of the Bombay-Burmah Trading Corporation.

Such of those characters as could be studied only in adult cardamom clumps were all studied recently, *i. e.* in December to February 1954. Sketches were drawn and photographs taken in February 1954.

The extensive cardamom plantations of the Singampatti Hills in which the Cardamom Research Station was situated contained about a million plants of the larger type of cardamom which were available for the study of the variability in this type.

Morphology and Habits of Cardamoms

Plant-height, leaf-size and panicle length. With the object of comparing the height, leaf-size and panicle length of the different cardamom types and bulk crops grown at the Research Station, measurements of these characters were made in all individual adult plants of the various types in 1954 and the average figures for these characters have been given in Table II. It should be mentioned here that in view of the fact that some of the Anamalais and Bodinayakanur types segregated for the characters studied, the measurements of these characters were confined to those segregates which were found to be true to the local type in each of these characters.

Table II

Cardamom—height, leaf-size and panicle length

Types	Height of aerial shoot Ft.	in.	Length of leaf lamina (Inches)	Breadth of leaf lamina (Inches)	Length of petiole (Inches)	Length of panicle (Inches)
(1) Singampatti Ceylon	10	1	24.5	5.8	0.8	22.3
(2) Singampatti indigenous	9	8	25.0	5.3	0.9	25.1
(3) Anamalais flexuous	9	2	25.8	5.8	0.9	22.6
(4) Anamalais erect	8	9	23.9	5.2	0.8	25.3
(5) Munzerabad	8	6	25.3	5.0	0.7	25.4
(6) Pattiveeranpatti	8	6	25.4	4.9	0.5	18.0
(7) Anamalais prostrate	8	4	24.0	5.0	0.6	21.0
(8) Bodinayakanur III	8	0	26.4	4.7	0.6	21.4
(9) Bodinayakanur IV	8	4	24.6	4.8	0.6	16.4

It may be observed from Table II that the first five types, *i.e.* those with erect or flexuous panicles are the tallest cardamoms, their heights ranging from 10 ft. 1 in. to 8 ft. 6 in. while the last four types with prostrate panicles are the shortest, their heights ranging from 8 ft. 6 in. to 8 ft. The differences in heights between these two groups of cardamoms when grown side by side under identical conditions are clear. The larger types of cardamoms have been seen to grow in very favourable situations even upto 15 feet and the smaller types upto 10 feet, but these are not common.

There does not seem to be much difference between the two groups with regard to the length of leaf lamina. The breadth of leaf lamina, however, is seen to be higher in the larger types with erect or flexuous panicles and ranging from 5.0 in. to 5.8in. In the smaller types with prostrate panicles it ranges from 4.7 in. to 5.0 in.

Th ere is a more distinct difference between the two groups of cardamoms in the lengt of peitole and it may be seen that the variability of this character within each group is ver little. There is also distinct difference between the two groups in panicle length.

It is thus seen that in all these characters except length of lamina, there are distinct differences between the larger and smaller cardamoms.

The pubescence of leaves. A study of pubescence of leaves of all types in the type collection, multiplication plots as well as Singampatti bulk fields was made. Every individual plant was examined for pubescence at various stages of their growth by feeling both the surfaces of leaves with the fingers. The hairiness was roughly classified as hairy, sparsely hairy and smooth (non-hairy). The results of these studies are given in Table III.

TABLE III

Pubescence of leaves—in Cardamom

Types	Leaves of Young seedlings		Leaves of adult Plants		Remarks
	Lower surface	Upper surface	Lower surface	Upper surface	
(1) Singampatti Ceylon . . .	Hairy	Smooth	Smooth	Smooth	
(2) Singampatti indigenous . . .	Do.	Do.	Do.	Do.	
(3) Anamalais flexuous . . .	Do.	Do.	Do.	Do.	
(4) Anamalais erect	Do.	Do.	Do.	Do.	
(5) Munzerabad	Do.	Sparsely Hairy	Hairy	Do.	
(6) Pattiveeranpatti	Do.	*Do.	Smooth	Do.	*The hairiness persists up to the 6th or 7th leaf only.
(7) Anamalais prostrate . . .	Do.	Do.	Hairy	Do.	
(8) and (9) Bodinayakanur III and IV	Do.	Do.	Do.	Do.	

It may be seen that the lower surface of the leaves of young seedlings of all types is hairy. The hairiness of the lower surface of the older leaves in the prostrate panicled types persists but that of the larger, erect or flexuous panicled types vanishes as the leaves grow older. The upper surface of the leaves of all types is smooth or only very sparsely hairy when young and uniformly smooth when old.

It is interesting to see that the Munzerabad type from Mysore with erect or flexuous panicles is similar to the smaller cardamoms with prostrate panicles with regard to hairiness. This strongly suggests that this type is a hybrid between the Ceylon (large) type and the smaller 'Malabar' type of cardamom with prostrate panicles, which is the predominant element of the cardamom crops of Mysore area. The Pattiveeranpatti type of small cardamoms with prostrate panicles, however, seems to occupy an intermediate position between the two groups of cardamoms, perhaps indicating a distinct feature of this type which is the exclusive type of the Pattiveeranpattiarea.

Nature of panicles. The cardamom types grown at the Research Station were all examined for the nature of panicles. *i.e.* whether they are of the flexuous, erect or the prostrate type and the results are given in Table IV (*See* also figure. 1).

1 2 3

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1 2 3 4

FIG. 1. Cardamom panicle types

FIG. 1 *A*—

1. Singampatti flexuous
2. Ceylon flexuous
3. Singampatti prostrate

FIG. 1 *B*—

1. Bodinayakanur prostrate
2. Pattiveeranpatti prostrate
3. Anamalais prostrate
4. Singampatti prostrate

TABLE IV

Panicle habit—in Cardamom

Variety	Parental character	Character of progeny			Total
		Erect	Flexuous	Prostrate	
1	2	3	4	5	6
(1) Singampatti Ceylon	Erect	42	..	1*	43
(2) Singampatti indigenous	Erect	27	..	..	27
(3) Anamalais flexuous	Flexuous	24	2	..	26
(4) Anamalais erect	Erect	29	..	3	32
(5) Munzerabad	Erect	23	1	1	25
(6) Pattiveeranpatti	Prostrate	..	5	23	28
(7) Anamalais prostrate	Prostrate	12	6	17	35
(8) Bodinayakanur III	Prostrate	..	15	26	41
(9) Bodinayakanur IV	Prostrate	..	5	34	39

Of the nine types studied in respect to this character, Singampatti-Ceylon, Singampatti indigenous, Anamalais erect and Munzerabad-Ceylon were almost pure for erect panicles. A flexuous type of Anamalais has given only two flexuous plants but as many as 24 erect ones. The other four types, Pattiveeranpatti, Anamalais prostrate, Bodinayakanur III and Bodinayakanur IV which were collected as prostrate panicled types have, as shown above not bred true to their types. They were evidently natural hybrids as their parent plants were open pollinated in their localities where different kinds of cardamoms, prostrate, flexuous and erect, were present.

In the Singampatti area wherefrom the Singampatti indigenous parent was obtained, the indigenous type alone is found and in this type the panicles are either erect or flexuous except in rare mutations. Accordingly this type had no chance of natural hybridization. It is also an observed fact that in the Singampatti area the flexuous nature is invariably associated with greater length of the panicle. When such growing panicles became weighted with the advancing increase in number and size (or weight) of fruits the panicles bend over and assume a flexuous nature and varying degrees of flexuousness are observable. Constant observation of a population of a million individual plants of this type at Singampatti confirmed the fact that flexuousness of the panicle* is definitely associated with the greater length of the panicle as well as the total weight of fruits on it. In other localities where prostrate-panicled forms and erect-panicled forms are grown side, by side, such hybrids showing flexuous panicles may arise, as in the case of the last three prostrate panicled plants from Anamalais and Bodinayakanur.

However, prostrate panicled plants do rarely occur in the Singampatti type, not more than half dozen plants in a million (Fig. 1 A. 3 and B. 4). Judged from the rarity of occurrence of the prostrate type at Singampatti it looks as if it originates as a result of rare mutation.

It is thus clear that there are only two types of panicles in cardamoms, *i.e.* (i) erect or flexuous and (ii) prostrate.

*perhaps rogues

Compactness of panicles. This character is dependent mainly on the internode length or distance between the racemes of panicles and is important as far as productivity is concerned, the more compact a panicle the more productive it is.

A study was conducted on the variability of this character in the Singampatti indigenous cardamom. Internode length of two or three typical panicles in each of 77 clumps selected at random were measured and the average internode length of each clump determined. The internode length of clumps varied from 0.6 in. to 2.2 in. with an average of 1.29 and the frequency array is given below :

Range of variability inches	Frequency	Frequency expressed in per cent	
0.5	..	..	
0.6	1	1.3	
0.7	6	7.8	
0.8	2	2.6	
0.9	2	2.6	
1.0	5	6.5	
1.1	7	9.1	
1.2	10	13.0	
1.3	10	13.0	Average—1·29"
1.4	12	15.0	
1.5	7	9.1	
1.6	4	5.2	
1.7	4	5.2	
1.8	4	5.2	
1.9	2	2.6	
2.0	..	..	
2.1	..	..	
2.2	1	1.3	
	77		

The vast variability of this character in the Singampatti cardamom is evident.

This character was studied also in the type collection. In this case compactness was classified into three broad classes, *viz.* dense, medium and sparse and the different types of cardamoms were classified for this character as shown below.

1 2 3 4 5

Fig. 2. Showing compactness of panicles

1. Bodinayakanur prostrate—compact
2. Singampatti flexuous—loose
3. Pattiveeranpatti prostrate—compact
4. Ceylon flexuous--loose
5. Anamalais prostrate—compact

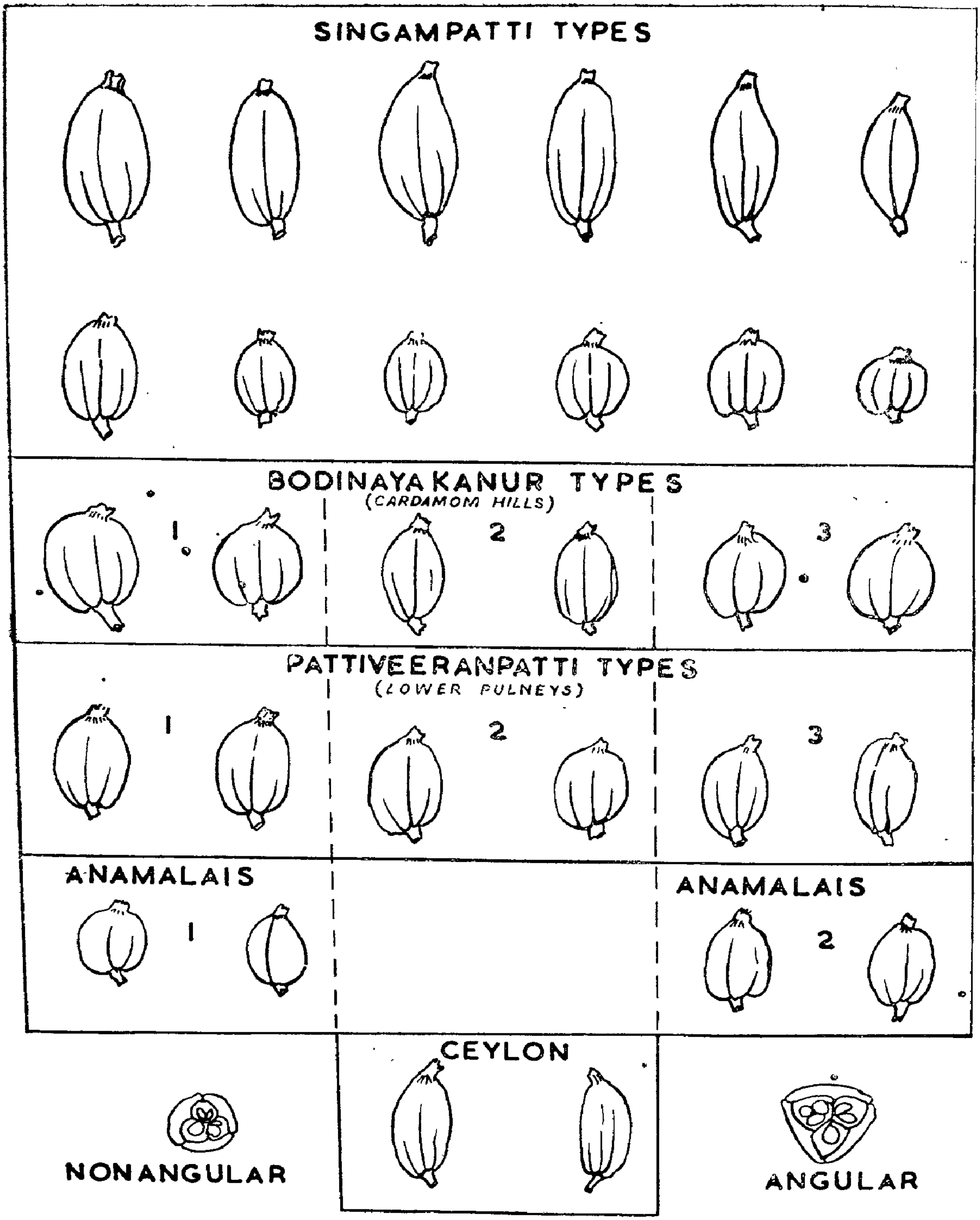

Fig. 3. South Indian cardamoms--fruit shape and size variations

TABLE V

Compactness of panicles of cardamom

Type 1	Panicle compactness: Dense 2	Medium 3	Sparse 4	Total 5
(1) Singampatti Ceylon	1	29	13	43
(2) Singampatti indigenous	..	8	19	27
(3) Anamalais flexuous	..	24	2	26
(4) Anamalais erect	4	24	4	32
(5) Munzerabad	..	16	9	25
(6) Pattiveeranpatti	5	20	3	28
(7) Anamalais prostrate	3	28	4	35
(8) Bodinayakanur III	10	29	2	41
(9) Bodinayakanur IV	30	9	..	39

The prostrate panicled types of cardamoms, especially the Bodinayakanur type [Fig. 2(1)] have densely packed panicles whereas the larger types with flexuous panicles have sparsely packed panicles. The Anamalais types as well as Pattiveeranpatti type seem to occupy an intermediate position with respect to this character. The hybridity or mixed nature of the Anamalais types is revealed by this character also.

Shape, size and colour of fruit. The Singampatti indigenous type of cardamom showed vast variability in shape and size of fruits (Fig. 3). The variability in fruit length and thickness are given in Table VI.

TABLE VI

Cardamom—Singampatti type—frequencies of fruit length and thickness

Fruit length (inches) 1	No. of fruits 2	Thickneess (inches) 3	No. of fruits 4
0.4	2	0.3	9
0.5	2	0.4	64
0.6	8	0.5	3
0.7	14		
0.8	29		
0.9	15		
1.0	5		
1.1	1		
Totals	76		76

It is seen that thickness of fruit is less variable than length, 84 per cent of the pods in a random sample being 0·4 in. thick. The length of the fruit on the other hand varies considerably and is largely responsible for the variability in size and shape of the fruit (Fig. 3—Singampatti types).

The fruit shapes in the individual plants of the various types collected and propagated through seed at the Research Station were examined and the results are presented in Table VII.

TABLE VII

Cardamoms—shape of fruit—frequencies of plants in the different groups for shape

S. No.	Type	Shape of fruit			Total
		Globular	Oblong	Long	
(1)	Singampatti Ceylon (flexuous or erect panicled)	..	42	1	43
(2)	Singampatti indigenous (flexuous or erect panicled)	..	27	..	27
(3)	Anamalais (flexuous panicled)	3	22	1	26
(4)	Anamalais (erect panicled)	..	30	2	32
(5)	Munzerabad (flexuous or erect panicled)	..	20	5	25
(6)	Pattiveeranpatti (prostrate panicled)	1	27	..	28
(7)	Anamalais (prostrate panicled)	1	31	3	35
(8)	Bodinayakanur III (prostrate panicled)	15	26	..	41
(9)	Bodinayakanur IV (prostrate panicled)	6	33	..	39

The larger types with erect and flexuous panicles have oblong or long fruits, whereas the types with prostrate panicles have round or medium shaped fruits (Fig. 3). It may also be seen that the types Anamalais flexuous and Anamalais prostrate are not pure for this character but seem to segregate. Evidently in this locality where the prostrate panicled and flexuous or erect panicled types are grown side by side, natural hybridisation has taken place.

It was observed that the fruit of the larger types are darker green in colour than those of the smaller type.

Weight of dry pods and percentage weight of dry to green pods.

One hundred normally developed pods of each of the different types of cardamoms were picked at random and their green and dry weights were determined. The dry weights were determined after drying duplicate samples of pods of each type to constant weight in a kiln. The percentage weight of dry to green pods were determined and the results are given in Table VIII.

TABLE VIII

Weight of green and dry pods of Cardamom

Types	Weight of one hundred ripe fruits (in gm.)	Weight of the same one hundred fruits after drying (in gm.)	Percentage weight of dry to green pods
(1) Singampatti Ceylon	96	25	26
(2) Singampatti indigenou	91	24	26
(3) Anámalais flexuous	119	31	26
(4) Anamalais erect	85	24	28
(5) Munzerabad	90	25	26
(6) Pattiveeranpatti	91	20	22
(7) Anamalais prostrate	74	20	27
(8) Bodinayakanur III	125	25	22
(9) Bodinayakanur IV	90	21	23

It is very interesting to see that the percentage weight of dry to green cardamoms is distinctly higher in the larger group of cardamoms than in the smaller. It may be noted that the Anamalais prostrate type goes with the larger group in this respect, indicating as previously mentioned, the hybrid nature of this type.

Structure of the cardamom flower. An examination of the flowers of all cardamom types revealed that they were all identical in structure and size and colour as described by Narasimhaswami (1937 and 1940) and other botanists referred to. However, their pedicel length varied slightly from type to type.

Flowering habits and periodicity. Some differences were noticed between the flowering habits and cropping periods of the two groups of cardamoms especially in the life of a flowering panicle. In the larger types the panicles may go on producing flowers for two or three seasons, but in the smaller type they die off in the season. However, it has been observed that these habits are influenced to a certain extent by varying weather conditions. Harvests could be begun in August in the smaller but only a month later in the larger, while harvests could be practically completed by February in the smaller type, fruits continue to ripen even up to May in the larger types.

Oil content of cardamom types. With a view to determine the oil content of pods of the different types of cardamom under study, samples of dry pods of these types were analysed for us by the Government Agricultural Chemist, Coimbatore, with the following results (Table IX).

TABLE IX

Oil content in cardamom

Types	Oil content (Per cent)
(1) Singampatti Ceylon	6.52
(2) Singampatti indigenous	6.96
(3) Anamalais flexuous	7.07

Types	Oil content (Per cent)
(4) Anamalais erect	Not analysed
(5) Munzerabad	6.02
(6) Pattiveeranpatti	5.98
(7) Anamalais prostrate	7.32
(8) Bodinayakanur III	7.33
(9) Bodinayakanur IV	7.78

It is interesting that the smaller types with prostrate panicles, with the exception of the Pattiveeranpatti type, have higher oil contents ranging from 7.32 per cent to 7.78 per cent, whereas the larger types with flexuous or erect panicles have lower oil content, except Anamalais flexuous, ranging from 6.02 per cent to 6.96 per cent. The peculiar behaviour of the Pattiveeranpatti type in this as well as in other features is important. The Anamalais flexuous must have acquired the high oil content by hybridisation with the smaller types which are grown mixed with it. Anyhow, the higher aromatic quality of the smaller cardamoms is quite evident.

Root studies. A study of the root system of cardamoms was attempted. Adult clumps of three types, Singampatti indigenous, Singampatti Celyon and a Singampatti indigenous with prostrate panicles were examined. The depth of penetration of the main roots, the number of main roots under each aerial shoot, the length of the longest root and the number of branch roots from the main roots were determined. A number of two-year old seedlings of different types were also examined for their root systems. The results are given in Table X.

TABLE X

Root studies on types of cardamoms

	Adult clumps				Two year old seedlings			
	Singampatti Ceylon	Singampatti indigenous	Singampatti prostrate	Bodinayakanur	Pattiveeranpatti	Anamalais prostrate	Singampatti indigenous	Singampatti Ceylon
Average No. of main roots per aerial shoot	11.0	10.0	9.4	7.2	7.2	8.2	6.4	26.4
Average length of longest root in cm.	45.7	70.0	69.9	34.4	30.2	30.6	31.0	33.2
Average No. of branch roots per main root	63.1	63.6	63.2	32.2	50.2	39.8	49.6	38.6
Maximum depth of penetration in cm.	18.4	16.4	15.6	..	..	..	..	..

It is seen that there are no appreciable differences among the three types grown under the same conditions except that the length of the main root was less in the Ceylon type. It is also seen that cardamom is a shallow rooted plant with a spreading root system indicative of a shallow surface feeder. If grown under different conditions of moisture levels in the soil, roots of cardamoms may be induced to go deeper in search of moisture as is reported in the case of the smaller cardamoms grown in Mysore. However, in two year old seedlings the number of main roots was found to be slightly higher in the prostrate panicled types of Bodinayakanur, Pattiveeranpatti

FIG. 4 (*A*). Larger type of cardamom with flexuous panicles

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FIG. 4 (*B*). Smaller type of cardamom with prostrate panicles

and Anamalais than in the larger Singampatti types. There was no appreciable difference in the length of main roots in the different types. The number of branch roots was conspicuously high in the Singampatti indigenous and Pattiveeranpatti types.

Study of cardamoms in their natural habitats. The surveys of the natural habitats and areas in which cardamoms are grown resulted in the collection of a vast fund of information on the conditions under which cardamoms grow in wild and cultivated states and the natural distribution of the different cardamoms in South India. It soon became clear that the cardamoms of South India fall into two main groups as found by Mayne (1942) and earlier worker quoted. They are :

(i) A smaller type which rarely if ever exceed about 10 ft. in height and is characterised by prostrate panicles with globular or oblong fruits (Fig. 4. B).

(ii) A larger type which under favourable situations may reach 15 ft. in height and is characterised by larger leaf lamina and by flexuous or erect panicles with larger longish fruits (Fig. 4A).

As cardamom has become an agricultural crop only in comparatively recent times, it can be considered to be only in the transition stage from the wild to the cultivated state. Even today there are many cardamom plantations planted with cardamom plants from self-sown seedlings taken directly from the jungle. Although introductions of cardamoms from region to region have taken place, the cardamom crops of most localities are derived from the wild cardamoms of the locality. From the natural distribution of the two main groups of cardamom mentioned previously, it is highly interesting to note that the larger type with erect or flexuous panicles and large fruits is indigenous to the extreme South of the Western Ghats, *i.e.* south of the Thamraparni river in the Tirunelveli District, while the smaller cardamom with prostrate panicles and smaller fruits is indigenous to the vast cardamom area extending from Thamraparni along the Western Ghats upto North Kanara in the north. This appears to indicate the natural adaptability of the larger cardamom to the lower but well distributed rainfall of the extreme south of the peninsula and the adaptability of the smaller "Malabar" cardamom to the wetter northern portions of the Western Ghats up to North Kanara.

The fact that the larger type with flexuous or erect panicles found in the Singampatti Hills was really the indigenous type of those tracts south of the Thamraparni river was not realised hitherto. Mayne (1942) expressed some doubt whether the cardamom found in this area was truly indigenous in this area as it was stated that it only occurs in the jungle areas which have previously been entered for extraction of timber. However, the following observations made by the senior author in these hills seem to prove conclusively that the larger cardamom found in the hills south of the Tharmaparni river is the indigenous type of those tracts :—

(1) The larger cardamom was the only type found growing wild in the jungles of these tracts when the area was originally cleared for cardamom cultivation about 35 years ago.

(2) The smaller cardamom with prostrate panicles could not be found growing wild anywhere in the jungles of these hills south of the Thamraparni river, whereas wild forms of the larger cardamom could be traced here and there in these jungles.

(3) The enormous amount of variability found in the morphological features of the fruit (Fig. 3) and panicle (Figs. 1 and 2) as well as in the productivity of the plants. Such great range of variability, as is well known, is seen only in the region of origin of a plant and seems to provide convincing proof that this is the indigenous cardamom of these hills.

The fact that this type largely occurs only in jungle areas which have previously been entered for collection of timber would seem to be explained easily. It is well known that in the evergreen jungles of the mountainous tracts of Travancore, Madras, Coorg and Mysore when the shade canopy of the jungle is lightened, cardamom seedlings frequently spring up spontaneously from seeds lying dormant in the soil, as experienced in the "*Male*" system of cardamom cultivation in Coorg. The same thing must have happened in these southern hill areas of the

Tirunelveli District when people entered these forests for collection of timber. This reminds one of what happened in the battle fields of Flanders, after the first World War. The dormant seeds of the red poppies which were lying buried deep under the soil were unearthed and brought to the surface by bursting shells. An unusual and surprising crop of poppies began to grow up and cover the battle fields and became a symbol and memorial to the dead.

It is thus clear that the larger cardamom found south of the Thamraparni river is really the indigenous type of these regions. It is interesting to note that in the island of Ceylon lying off the extreme south of the Indian peninsula, only the larger type of cardamom, var. *major* is found in the wild and cultivated state. It should be mentioned here that until the smaller cardamom with prostrate panicle was introduced to Ceylon in recent times from South India it was unknown in that island (Molegode, 1938). The land connection between the extreme south of India and Ceylon, which existed millions of years ago, is well known to geologists and biologists. The great similarity between the flora and fauna of these two land masses is proof of this fact. Hooker and Thomson (1855) describing the flora of Ceylon states that "a dense forest clothes all the humid southern and western parts of the island, composed of plants eminently characteristic of Malabar". They further state that "the flora of Ceylon (which probably does not contain 3000 Phanerogamic plants) is on the whole identical with that of the peninsula". It would, therefore, seem reasonable to infer that the mountainous region south of Thamraparni river in Tirunelveli District and the island of Ceylon constitute the original home of the larger cardamoms var. *major* Thw, while the Western Ghats extending from river Thamraparni northwards to North Kanara to be the original home of the smaller "Malabar" cardamom.

Discussion

The genus *Elettaria* is one of the few compact and small natural groups of plants, whose original home is the mountains of the south western parts of the Indian peninsula and the nearby island of Ceylon. As mentioned previoulsy, since cardamom is at present only in the transition stage from the wild to the cultivated state, it is of very great interest from the point of view of the evolution of cultivated forms of cardamom from the wild ones. Selection of cardamom for productivity and other qualities by man has not yet brought about much difference between the wild and cultivated forms. Introductions from one tract to another have taken place, resulting in hybridity and a certain amount of mixing although this was held in check in many cardamom growing areas by the clonal method of propagation of the crop.

The present studies on the distribution, habits and morphology of the different cardamoms in their natural habitats and when grown side by side under identical conditions revealed that the cardamom of each locality or habitat forms a freely interbreeding population, the individuals of which represent various recombinations of the genic composition of the local population. The different types of cardamom collected from the different regions (habitats) and grown side by side under identical conditions at the Cardamom Research Station, Singampatti Hills, for seven years, revealed that they bred true to their different genotypic constitutions and that their outstanding morphological and habit differences could not be modified by the environment obtainable at the Research Station in the Singampatti Hills, 4700 feet above sea level. The experiment of growing the nine different local types side by side also showed that populations of cardamoms now found to occupy different habitats have become differentiated genetically from one another and some of them have acquired different characteristics such as size of plants, leaves and fruits, habits of the panicle and adaptability to varying climatic and ecological conditions. The best way to understand the evolutionary processes that led to the differentiation and distribution of the different cardamom populations in their respective habitats seems to be to distribute the various ecogeographical types of cardamoms as a 'cline' as suggested by Huxley (1945) and adopted by Gregor (1937-38) in the case of ecological adaptation of races of *Plantago maritima* L.

It has been pointed out earlier that from the natural distribution of the two main types within the genus *Elettaria* there were indications that the larger cardamom with erect or flexuous panicles and longish fruits is indigenous to the extreme south of the Western Ghats south of the

Thamraparni river in the Tirunelveli District, while the smaller cardamom with prostrate panicles and smaller globular or oblong fruit is indigenous to the vast mountainous area extending from Thamraparni river upto North Kanara in the north. In this genus as a whole where there is no variability at all in the structure of the flower, the outstanding morphological and habit characteristics which would help us to distinguish the various ecogeographical types of cardamom in South India are the following :—

(1) Height of plant

(2) Habits of panicles— erect, flexuous or prostrate

(3) Compactness or looseness of panicles based on internode length and length of pedicels

(4) Fruit characters such as shape, size and colour

(5) Size of the leaf and petiole length

(6) Pubescence of leaves

(7) Flowering habits and periodicity

Judging on the basis of these characteristics, their distributions and associations in the different ecogeographical types, it seems possible to trace the probable evolutionary history of the genus *Elettaria* Maton, (the true cardamoms) and the natural evolution of its ecogeographical types. *Elettaria* Maton, must have first originated from a closely allied Zingiberaceous, plant, perhaps the *Amomum* type, millions of years ago when the island of Ceylon and South India were in a homogenous block (formed a single land mass). The region of origin may have been the mountainous region in the extreme south of that land mass now corresponding to the island of Ceylon and the mountainous region extending from the extreme south of the Indian peninsula to North Kanara. The original form of *Elettaria* may have been similar to the larger type of *Elettaria*, *Elettaria cardamomum* Maton var. *major* of the present day with erect panicles and large, longish fruits which were perhaps very much less aromatic than not only the fruits of the present day smaller cardamom but also those of the larger cardamom. It is noteworthy in this connection that the seeds of *Amomum* and certain Zingiberaceous plants very nearly related and vegetatively similar to *Elettaria* have also the aroma of *Elettaria* seeds but to a very much lesser degree. Such Zingiberaceous genera closely allied to *Elettaria* are present in large numbers in the Western Ghats, the original home of *Elettaria*. They were also observed recently by the senior author to grow in abundance in the Eastern Ghat regions of the Koraput District of Orissa and the forests of Assam. They are also reported to be present in the foot hills of the Himalayas round about Darjeeling and in Nepal and Bhutan. Evidently only the climatic and ecological conditions of the extreme south of the Indian peninsula and Ceylon favoured the evolution and maintenance of the genus *Elettaria* Maton.

It has also become sufficiently clear that the larger cardamom of the extreme south of the peninsula and Ceylon was the original cardamom from which the smaller type has originated. The following is the important evidence which led to this inference :—

(i) The greater range of variability in respect to the morphology of the panicles and the fruits as well as the productivity of individual plants in the larger cardamom than in the smaller cardamom. In the latter the variability in these features even among its forms is limited.

(ii) The habitat of the larger cardamom is always the evergreen jungles and it is satisfactorily productive only between the elevations of 3000 and 4500 feet. The smaller cardamom is usually productive from an elevation 4500 feet down to about 2000 feet. The fact that a form of the smaller cardamom, peculiar to and cultivated in North Kanara is productive even at an elevation of 1500 feet, is indicative of a tendency of the smaller cardamom to gradually come down to lower elevations, which is undoubtedly a greater advance in evolution.

(iii) The local types of the smaller variety, especially of Pattiveeranpatti, grow well and give good yields even with 50 or 60 inches of rainfall per year and under jungle which is partially deciduous, provided the soil is rich and moisture retentive.

(iv) Prostrate panicled plants and plants with globular fruits as well as plants combining both these characters were observed to occur as mutations in the larger cardamom of the Singampatti Hills situated south of the Thamraparni river.

This is the important evidence to show that the more delicate but adaptable smaller cardamom with prostrate panicles has originated from the earlier, but less accommodative and more variable larger type.

The question now arises as to how the two main groups of cardamoms, the larger and the smaller, came to be distributed, the former in the hills south of the Thamraparni river and the latter in the hills north of this river upto North Kanara. This can be understood only if we go into the ecogeographical differences between the two regions, *i.e.* the differences in the general elevation, amount and distribution of rainfall, nature of the forests as well as those of other ecological conditions prevailing in the two regions. The hills immediately south of Thamraparni in the Singampatti and the Kalakad areas, the home of the larger cardamom in India, are on an average 3000 to 5000 feet above sea level and form high mountain ranges covered with thick evergreen forests. In this southern home of cardamom grass-covered hills devoid of forests are few and far between. It is also noteworthy that the higher ranges of these hills are uninhabited and the ecological conditions of these high hills were not known to have been disturbed very much. As mentioned previously, generally the rainfall in these southern portions of the Western Ghats where cardamom is found, is much less, *i.e.* 100 to 150 inches, than in the north. The amount of rainfall increases as we go north. The rainfall, however, is much better distributed in these southern hills than in the northern hills where it is more seasonal and broken by long spells of dry weather. In the extreme south of the peninsula, the North East Monsoon extends up to February while in the regions north of Shencottah it is usually over by November. This chiefly accounts for the much better distribution of rainfall in the south. Thus the ecogeographical conditions in the hills south of Thamraparni seems to be eminently suited to the larger cardamom. The conditions obtainable in the south-western side of the high mountains of Ceylon also seem to be similar and favourable for the growth of the larger-cardamom.

The ecogeographical conditions in the Western Ghats north of Thamraparni river, especially in the Cardamom Hills of Travancore, are vastly different from the southern region. The very irregular distribution of rainfall and the scantiness and shortness of the North East Monsoon in these northern regions has already been referred to. Certain important features with regard to the rainfall in the Western Ghats should be clearly understood. The sources of rainfall for these Western Ghats of South India in general are the South West Monsoon, North East Monsoon and summer showers from March to May. Most of the rainfall in the Ghats is received during the South West Monsoon. In the more westerly portions of the hills, the rains at this period are very heavy and continuous, but they are much less in more easterly areas, decreasing as we go further east along the hills. These easterly areas in the hills, however, experience strong west winds, much cloud and fairly frequent showers. This rapid decrease of South West Monsoon rains in the more easterly portions of the Western Ghats is characteristic of the Cardamom Hills of Travancore and partly the cardamom growing areas further north such as the Anamalais, Coorg and Mysore, all of which are undulating hill regions generally 3500 down to 2000 feet in elevation. The rainfall in the Cardamon Hills of Travancore is only 70 to 80 inches and in the Pattiveeranpatti area on the eastern ridge of the Ghats only 50 to 70 inches. However, in the Anamalais, Coorg and Mysore, as we go still further north, much higher falls of rain are received in the South West Monsoon but very little in other seasons. Another remarkable feature of these northern hills which form an undulating plateau is the existence of vast grass lands covering the hills. Generally only the valleys and the saddles in this undulating plateau are wooded. These forests in the valleys and saddles are only partially evergreen, a good

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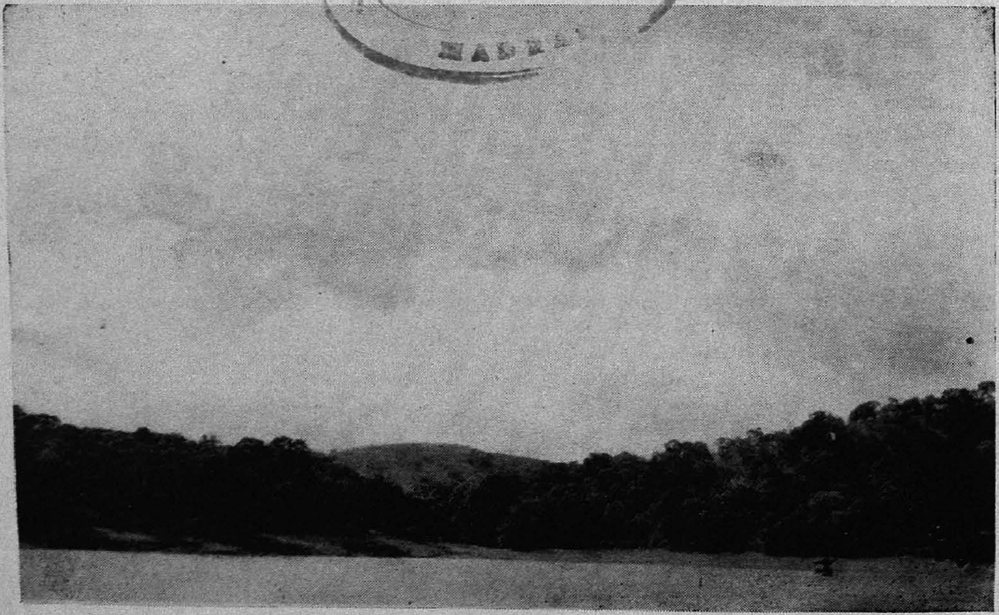

FIG. 5. Two views typical of the Cardamom Hills of Travancore taken from Periyar Lake. Note the grass covered hills and the wooded valleys. The forests in the bottom of the valleys are sub-merged and destroyed by the waters of the Lake

proportion of the trees being deciduous, shedding their leaves in summer. To understand these peculiar ecological conditions one has actually to see the Cardamom Hills of Travancore, the original home of the smaller cardamom (*See* views in Fig. 5). The deforestation of the hill slopes in these regions must have been brought about partly by man, the original hill tribes inhabiting these hills, who periodically cleared the forests for cultivation of grain crops and partly by natural forces, working through thousands of years. One, if not, the most important factor which assisted and accelerated the process of deforestation in these hills seems to be the forest fires which rage in these hills every year. It is needless to say that these constant (annual) fires in the dry season constitute a menace to tree-growth in these areas. The wooded valleys and saddles are, however, not usually affected by these fires. The shallowness of the soil and existence of rock, a foot or two below ground level, all on account of gradual soil erosion, would have also perhaps turned some of these hillslopes from forests to grass lands in the course of a long period of time. From the vast variations in the quantity and periodicity of rainfall combined with the variations in elevation and topography, peculiar local changes in the ecological conditions are also naturally created within an ecogeographical region. These differing conditions are bound to evolve local populations within the smaller cardamom population. It may also be inferred from all these that long ago these hills also were covered with thick forests and therefore the rainfall would have been also much more and perhaps more evenly distributed then, than at present. If these inferences are correct it can be argued that the original *Elettaria*, the larger type, may have been the original type distributed throughout the region, north and south, where cardamoms of both the larger and smaller types are seen to grow wild at present. The case of *laxiflora* (Narasimhaswamy 1940) of the larger type seems to give a very good evidence to indicate the correctness of the above inference. Mayne (1942) found this form of the larger type to occur wild in the Hills of the Gandamanayakanur Zamindari in the Madura District. These hills are to a certain extent segregated from the Western Ghats, being a range of fairly high hills projecting out into the plains of Madura District from the Western Ghats. The existence of this form of the larger type in such a segregated area is an illustration of discontinuous distribution of a type and indicates that the larger type of cardamom may have existed in the regions north of Thamraparni, in very ancient times and largely died out long ago. It should, however, be mentioned here that *laxiflora* has one feature in common with the smaller type, *i.e.* the creeping nature of the panicle, a character apparently evolved in this northern region. It is not improbable that pockets of discontinuous distribution of the larger type may still be traced in some unexplored localities (pockets) in the interior of the Western Ghats, especially in some of the smaller ranges of hills with higher elevations and favoured with suitable amounts of rainfall conditions, evergreen forest and such other favourable ecological conditions. The gradual changes in the ecological conditions of the mountainous regions north of the Thamraparni river, described above, which took place through a long period of thousands of years were evidently not favourable for the continuance of the less accommodative larger type of cardamom. Naturally, as in the case of so many other plant populations and evergreen jungle trees, the larger type of cardamoms generally disappeared from these northern regions giving place to some of its mutations which were smaller in the size of the vegetative parts and fruit, with a creeping habit of the panicles and a physiological build up adaptable to the changing ecological conditions. As types suitable to the changing ecological conditions, these smaller types seem to have been more adaptable to lower elevations, irregular rainfall and the partially deciduous nature of the forests under which they grow. These smaller forms are also seen to be more delicate in respect of resistance to the dreaded mosaic disease of cardamom and are more susceptible to it than the larger, type. In the process of evolution of the smaller type of cardamoms in this northern region at the expense of the larger, the slightly varying ecogeographical conditions existing in different localities of this northern region, which were referred to previously, had their own parts to play in the evolution of different local populations of the smaller type.

As an example the prostrate panicled form which is indigenous to the Lower Pulneys of Madura District seems to be definitely distinguishable from those found indigenous in the Cardamom Hills of Travancore and Anamalais. A review of the morphological features of

the various local types of the smaller cardamom reveals that the one from Pattiveeranpatti (Lower Pulneys) differs from the others in the following features ;—

(i) The Pattiveeranpatti type is the tallest among the smaller types.

(ii) It has the shortest petiole among the smaller cardamoms.

(iii) It has the largest leaf lamina among the smaller cardamoms.

(iv) It has the peculiar feature that the hairiness of its leaves persists only up to the sixth or seventh leaf. In this respect it occupies a middle position between the smaller and larger cardamoms.

(v) It has mostly, almost exclusively, oblong-shaped fruits unlike the predominantly spherical fruits of the other smaller cardamoms.

(vi) It has the lightest fruit and lowest oil content.

The above peculiar features indicate that this cardamom of the Lower Pulneys is a distinct local type of the smaller cardamom. (*)

Another interesting local type of the smaller cardamom is the one found cultivated in North Kanara. The fruits of this type are distinctly three angled and ovoid in shape (Mayne 1942). One of the most distinguishing features of this type is its capacity to be productive at low elevations of 1500 to 2000 feet above sea level at the lower ends of hill valleys, while none of the other cardamoms are productive below 2000 feet elevation. This is evidently a local type of the smaller cardamom which is adapting itself gradually to lower elevations and shows really a very important change in habit as a result of the peculiar ecological conditions to which it is subjected. A map showing the natural distribution of the ecogeographical types of *Elettaria* is given in the beginning.

As stated previously the distribution of the various ecogeographical types of cardamom seems to form an 'ecocline'. The original type, the larger cardamom, once upon a time inhabited the entire cardamom tract of the present day, from Ceylon to North Kanara. It was a freely interbreeding population, the individuals of which represented various recombinations of the genic composition of the original cardamom. In the course of thousands of years the ecogeographical conditions in the hills north of the Thamraparani began to exhibit considerable changes, such as those described above. These ecological changes have had far reaching influence on the genetic composition of the cardamom population in relation to its environment, or in other words, the physiological reaction of the population to its environment. The result would have been a series of mutations, the fittest among them continuing the race and the rest gradually disappearing. The type of population which adapted itself to these changing ecological conditions was, as shown clearly earlier, the smaller cardamoms with creeping panicles and roundish or oblong fruits. The particular ecogeographical conditions of the Lower Pulneys and the Sirsi area of North Kanara gave rise to differing local populations of the smaller cardamom, while those of the segregated high hill range of the Gandamanayakanur area maintained a small population of the larger cardamom with longish fruits. The changes in the genetic build up of these populations must have been effected through a series of mutations which occurred in the course of a very long period of time. The occurrence of such mutations even at the present time in the larger cardamom in the southern region has been pointed out earlier. In the Singampatti area such prostrate panicled mutants with spherical or oblong fruits were

(*) It should also be specially mentioned here that the Pulney Hills also, just like the Gandamanayakanur Hills, project out from the Western Ghats into the Madura District and the Lower Pulneys, especially, are hills partially segregated from the Western Ghats. Consequently the ecological conditions of the Lower Pulneys are different from the Cardamom Hills and this may account for the evolution of this peculiar local type of the smaller Cardamom.

seen to be rather rare, only half dozen plants in a million. In a wild state these mutants have very little chance of survival in the southern region in competition with the larger population, while in the north, as described above, they gained supremacy under the ecogeographical conditions favourable to them.

It must have become clear by now how unsatisfactory are the classical taxonomic methods in tracing the natural relationships among the various ecogeographical populations of cardamom. As already stated each of such population is seen to be freely interbreeding within itself and these different populations are separated from each other by geographical and ecological barriers. To describe a type or the so called 'variety' of cardamom in the classical taxonomic language is impracticable as the morphological variations among the individuals of a variety or ecogeographical population are vast and innumerable. Therefore, groups of plants or genera such as *Elettaria* seem to offer very satisfactory material for the application of the modern conceptions of ecological differentiation and evolutionary taxonomy as was suggested by Clausen, Keck and Hiesey (1939), Huxley (1945), and adopted by Gregor (1937 and 38) in the case of ecological adaptations of races of *Plantago maritima* L. These modern conceptions of ecological differentiation and evolutionary taxonomy are vividly reviewed by Heslop Harrison (1953) in his book, *New Concepts in Flowering Plant Taxonomy.*

The attempts at classification of cardamoms of South India, according to the classical taxonomical methods, by the early taxonomists, *viz.*, Thwaites (1861-64), Baker (in Hooker 1894) and Schumann (1904) led them all to the general conclusion that the cardamoms, *Elettaria* Maton, fall into two main distinct groups, the larger and the smaller. The former two of these workers named the larger type found in Ceylon as var. *major*, a single variety of *Elettaria cardamomum* Maton, while Schumann (1904) raised these two groups to species rank as *E. cardamomum* L. Maton and *E. major* Sm. According to the modern 'experimental' method of taxonomy, if two very closely allied groups of plants of the same genus, although morphologically different and ecologically and geographically segregated, freely interbreed and form stable hybrid populations when grown together, or in other words, two groups of plants between which there is no genetic-physiological barriers, they should be considered as belonging to one '*ecospecies*' which often corresponds to the taxonomic *species*. As has been shown, different forms of the larger and smaller cardamoms when grown side by side bred true to their parental forms and some of them which were hybrids between the larger and the smaller cardamom segregated into their parental forms. Artificial hybrids were also made but these hybrids could not be pursued beyond raising first generation plants. In nature also plants which seem to be hybrids between the larger and the smaller cardamoms do occur, such as larger forms with prostrate panicles and globular fruits, but whether they are capable of surviving in competition with their parental forms in a particular environment is not known. However, from the ecogeographical distribution of the different cardamom populations and the fact that the species *Elettaria cardamomum* comprises a freely interbreeding population, the genus *Elettaria* seems to be a '*cenospecies*' with a single '*ecospecies*' corresponding to the taxonomic species, *Elettaria cardamomum* Maton. This '*ecospecies*' comprises two '*ecotypes*', *i.e.* the larger and the smaller cardamom populations. As described previously the smaller cardamoms may be divided into three different local populations, the one found in the Cardamom Hills of Travancore, Anamalais, Mysore and Coorg, the second found in the Lower Pulneys and the third found cultivated in Sirsi, North Kanara.

Whether Schumann's division of *Elettaria* into two species, corresponding to the ecotypes mentioned above, is justified or not, can be decided only after the application of the powerful analytical tool of systematic hybridisation and study of the hybrid generations. This can be achieved only through decades of intensive study of successive hybrid generations. This is for posterity to accomplish. A careful study of the cytogenetics of cardamoms, which has not yet been done, should also greatly help in clearing up this issue.

Molegode's (1938) third variety, the Mysore variety, does not seem to have originated in Mysore, but according to Mayne (1942) was introduced to Mysore from Ceylon in earlier times and belongs to the larger *ecotype*. *Mysorensis* in Mysore shows all the three kinds of panicles, flexuous, erect and prostrate on account, perhaps, of hybridity. Narasimhaswamy

(1940) also mentions three varieties, the second of which, var. *mysorensis* corresponding to var. *mysorensis* of Molegode (1938) and a third '*variety*', *laxiflora*. *Laxiflora* is raised to the rank of a '*variety*' based mainly on the laxness of racemes that have flowers with long pedicels elongated fruits and glabrous leaves. In view of the facts that this *laxiflora* is a member of the larger group of cardamoms and found mainly in a segregated locality, *viz*. Gandamanayakanur area, North of Thamraparni it must be considered, as previously emphasised, only as a separate local population of the larger cardamom. It is interesting that Narasimhaswamy (1940) has found this also in the Mysore State. Perhaps it has naturally originated also in a certain locality in Mysore under an environment similar to the one in Gandamanayakanur Hills. The small populations of *laxiflora*, however, seem to have found it more convenient to adopt in both these localities a creeping habit of the panicle and longer pedicels giving laxness to the panicle. This is perhaps a good example of parallel evolution in two different localities.

In view of the present distribution of the ecogeographic populations of cardamoms in South India as an "*ecocline*" and to help future systematists in their work, the various populations may be named as given below. The naming is as suggested by Clausen, Keck and Hiesy (1939).

Elettaria is a single "*cenospecies*" completely separated from other closely allied genera such as *Amomum* by genetic barriers. The *cenospecies* , *Elettaria*, consists of only one *ecospecies* comprising all cardamom populations of South India and Ceylon and may be termed *ecospecies—Cardamomum*. The *ecospecies—Cardamomum* consists of two *ecotypes* corresponding to the two ecogeographical populations, the larger and the smaller cardamoms. The larger *ecotype* may be named *ecotype-major*, while the smaller may be named *ecotype-minor*. Within the large population of *ecotype-major* there seems to be only one minute local population found segregated in Gandamanayakanur Hills as well as in a locality in Mysore. This local population may be named *ecotype-major*, local type-*laxiflora*. *Mysorensis* of Narasimhaswamy (1940) may perhaps be another local type of the *ecotype-major* but it requires further evidence to establish it.

The smaller population, *ecotype-minor*, may be divided into three main local populations or *local types*. The one found in the vast region comprising the Cardamom Hills of Travancore, Anamalais, Coorg and Mysore may be named, *ecotype-minor*, local type-*travancorica*. The distinct local population of Lower Pulneys may be named *ecotype-minor*, local type-*oblongata*, as it is characterised by oblong fruits. The peculiar local population cultivated in Sirsi, North Kanara may be named *ecotype-minor*, local type-*kanarensis*. Other local types of both the ecotypes may occur or may be in the process of evolution. These have yet to be discovered and described by workers of the future.

Summary

(1) An extensive survey of the South Indian portions of the Western Ghats where cardamoms are indigenous resulted in the collection of a vast fund of information on conditions under which cardamoms grow, the variability of elevations suitable for cardamom, nature of forest, the amount and distribution of annual rainfall as well as the natural and ecological distribution of the various cardamom types or populations met with in South India. A collection was also made of representative plants of the different types of cardamoms found in these tracts.

(2) These representatives of types collected during the survey were grown side by side under identical conditions at the Research Station and their morphological and habit differences studied in detail.

(3) These studies revealed that the cardamoms in general and particularly of each locality or habitat forms a freely interbreeding population, the individuals of which represent various recombinations of the genic composition of the local population.

(4) Populations of cardamoms now found to occupy different habitats are seen to have become differentiated to a considerable extent genetically and physiologically and have acquired different characteristics, morphological as well as in adaptability to the varying ecological conditions.

(5) It also soon became clear that the cardamoms of South India fall into the following two main groups as found by earlier workers.

(i) A smaller type which rarely if ever exceeds about 10 feet in height and is characterised by prostrate panicles with globular or oblong fruits.

(ii) A larger type which under favourable situations may reach 15 feet in height and is characterised by larger leaf lamina and by flexuous or erect panicles with larger longish fruits.

(6) The larger type with flexuous or erect panicles was found to be indigenous to the mountainous tracts south of the Thamraparni river while the smaller type with creeping panicles was found indigenous to the vast cardamom area extending from Thamraparni along the Western Ghats up to North Kanara in the north.

(7) The distribution of the various ecogeographical types of cardamom seems to form an *'ecocline'*. The original type, the larger cardamom seems to have, once upon a time, inhabited the entire cardamom tract of the present day, from Ceylon to North Kanara. However, the ecological changes which occurred in the cardamom tracts north of Thamraparni river during the course of a long period of thousands of years resulted in the evolution of the smaller type of cardamoms adaptable to the changing environment through a series of mutations and the gradual disappearance from these northern regions of the original large type not suited to the new environment.

(8) The state of affairs described above makes one to realise how unsatisfactory are the classical taxonomic methods in tracing the natural relationships among the various ecogeographical populations of cardamom. The genus *Elettaria*, therefore, seems to offer very satisfactory material for the application of the modern conceptions of ecological differentiation and evolutionary taxonomy. Accordingly, the genus *Elettaria* seems to be a *'cenospecies'* with a single *'ecospecies'* corresponding to the taxonomic species *Elettaria cardamomum*, Maton. This *ecospecies* comprises two *ecotypes*, *i.e.* the larger and the smaller cardamom populations.

The larger *ecotype* may be named *ecotype-major* while the smaller may be named *ecotype-minor*. Within the large population of *ecotype-major* there seems to be only one minute local population found segregated in Gandamanayakanur Hills as well as a locality in Mysore. This local population may be named *ecotype-major*, local type-*laxiflora*.

The smaller population, *ecotype-minor*, could be divided into three main local populations or *local types*. The one found in the region comprising the Cardamom Hills of Travancore, Anamalais, Coorg and Mysore may be named, *ecotype-minor*, local type-*travancorica*. The distinct local population of the Lower Pulneys may be named, *ecotype-minor*, local type-*oblongata* as it is characterised by oblong fruits. The peculiar local population cultivated in Sirsi, North Kanara, may be named *ecotype-minor*, local type-*kanarenis*.

PART II

AGRICULTURAL VALUE OF SOUTH INDIAN CARDAMOMS

THE ecogeographical races of cardamoms of South India have been defined in Part I of this paper. The climatic, environmental, soil and other conditions under which cardamoms are cultivated and wild cardamoms grow were also described. It was also pointed out that selection of cardamom for productivity by growers has not yet brought about much difference between the wild and cultivated forms, neither does there exist any recognised scientifically selected agricultural strain of cardamom. It was also with the aim of isolating high yielding strains of cardamoms that collections of seeds of single plants showing high productivity and resistance to diseases from several localities were made and grown side by side in trial plots at the Cardamom Research Station, Singampatti Hills. The results of such attempts at isolating desirable high yielding strains of cardamoms are discussed in this part of the paper.

Material and Methods

It was stated in Part I of this paper that seedlings of all types of cardamoms collected, nine in all, were raised in nurseries and planted side by side as trial plots in 1948. One of the objects of these trials was to test the comparative productivity of these different types. These trials were laid out in randomised blocks, each replication of a variety having five clumps.

Besides the above types, 120 single plant selections, made by the senior author in 1942, from the indigenous larger cardamoms of the Singampatti Hills were available for study. These selections were made from three extensive plantations covering a total of 1500 acres. The selections were based mainly on high productivity, bold globular, ovoid or oblong and large fruits and other outstanding differences in the nature of panicles. These selections were also in a small measure representative of the vast variability in morphological and productivity features met within the indigenous cardamom of the Singampatti Hills.

The 120 single plant selections were vegetatively propagated under a preliminary yield trials. The recording of yields and other useful economic characters continued year by year from 1944-45 to 1947-48.

In the year 1948-49, the best seven yielders from among them were planted out vegetatively in yield trials with Singampatti bulk and a Ceylon type as controls. The lay-out of these trials was in randomised blocks replicated four times. These trials began yielding from 1951-52 and harvests were made and recorded in three succeeding years until 1953-54.

Yield Trials

Yield trials of Singampatti cardamoms. A preliminary yield trial of clones of 120 best types of single plant selections of the indigenous Singampatti cardamoms (larger type) which had been laid out under the Research Scheme of the Bombay Burmah Trading Corporation, Ltd., three years prior to the starting of the scheme was made available for further study under this scheme. The recording of single plant yields was in progress.

This work was continued from 1944-45 to 1947-48. Several of these selections were found to give consistently higher yields than the control (Singampatti bulk). The yields given in the various years by ten of the best selections are tabulated below :

TABLE XI

Yields of the best Singampatti Selections—Preliminary Yield Trials of Cardamom
(Average yield of green pods expressed in pounds per acre and as percentage on control)

Set No.	Selection No.	1944-1945		1945-1946		1946-1947		1947-1948	
		Per acre in lb.	As percentage on control	Per acre in lb.	As percentage on control	Per acre in lb.	As percentage on control	Per acre in lb.	As percentage on control
1	2	3	4	5	6	7	8	9	10
I	Control	412.3	100.0	777.8	100.0	248.6	100.0	289.0	100.0
	87	1088.0	263.9	1547.0	198.4	580.1	233.1	663.0	255.7
	89	569.5	138.1	1024.3	131.6	340.0	136.7	484.5	187.7

1	2	3	4	5	6	7	8	9	10
III	Control	467.5	100.0	748.0	100.0	250.8	100.0	552.5	100.0
	39	514.3	110.0	1032.8	138.1	357.0	142.3	612.0	110.2
	41	565.3	120.9	930.8	124.2	453.3	180.7	671.5	120.9
IV	Control	459.0	100.0	841.5	100.0	297.5	100.0	191.3	100.0
	49	633.3	137.9	1100.8	131.0	470.3	158.1	561.0	292.5
	50	667.3	145.3	1317.5	156.6	664.4	223.3	680.0	432.8
	71	365.5	79.6	1045.5	124.6	681.4	229.4	663.0	349.3
V	Control	297.5	100.0	705.0	100.0	331.5	100.0	195.5	100.0
	81	607.8	204.3	1381.3	196.0	722.5	217.9	433.5	221.7
	85	284.8	95.7	922.3	135.5	521.3	157.3	295.5	153.6

It may be seen from the yields of these selections during the four seasons that several of them gave two to four times the yield of the bulk indicating the vast variability among the individual plants of the Singampatti indigenous type of cardamom in their productivity (yield).

In the year 1948-49, the clones of the best seven yielders among these selections were planted out for comparative bulk yield trials with Singampatti bulk and Singampatti Ceylon. These bulk trial plots began yielding in 1951-52 and the first harvests were made in that year. The harvests continued for two more years, 1952-53 and 1953-54. The cumulative yields of these selections for these three years are analysed below :—

Object. To compare the yield of the Singampatti bulk with the yield of the Singampatti selections.

Treatments :—

(1) Singampatti bulk (control)
(2) Singampatti (Ceylon type)
(3) Selection No. 81
(4) Selection No. 71
(5) Selection No. 89
(6) Selection No. 87
(7) Selection No. 50
(8) Selection No. 41
(9) Selection No. 39

Lay out :—Randomised blocks replicated four times with 20 clumps in each

Area of each plot : 3 cents

Date of planting : July 1948

Date of collection of data : October 1951 to April 1952

September 1952 to April 1953

September 1953 to February 1954.

The total yield of green pods in pounds for the three seasons 1951-54 are given below :—

Selections								Singampatti Ceylon	Singampatti bulk (control)
	81	71	89	87	50	41	39		
Yields	131	119	86	73	70	58	58	29	27
Conclusion	81	71	89	87	50	41	39	Ceylon	Control

It may be seen that all these seven best selections of the Singampatti cardamoms gave much higher yields than the local bulk, all of them giving two to five times the yield of the bulk.

Varietal trials of South Indian cardamoms. Seedlings of the nine South Indian types of cardamom collected during the survey of the cardamom growing tracts during the years 1944-46 were raised in nurseries and planted out into the field in 1948 for a comparative study. The harvests commenced in 1951-52 and have been in progress since then. The cumulative yields of these types for these three years are analysed below :—

Object : To compare the yields of the South Indian cardamom types.

Treatments :

(1) Singampatti Ceylon

(2) Singampatti bulk (control)

(3) Anamalais flexuous

(4) Anamalais erect

(5) Munzerabad

(6) Pattiveeranpatti

(7) Anamalais prostrate

(8) Bodinayakanur III

(9) Bodinayakanur IV

Lay out : Randomised blocks replicated six times with 5 clumps in each

Area of each plot : 0.75 cents

Date of planting : July 1948

Date of collecting data : October 1951—June 1952

September 1952—May 1953.

September 1953—January 1954

The total yield of green pods in ounces for the three seasons 1951-54 are given below :—

	Singampatti Ceylon (1)	Singampatti bulk (control) (2)	Anamalais flexuous (3)	Anamalais erect (4)	Munzerabad (5)	Pattiveeranpatti (6)	Anamalais prostrate (7)	Bodinayakanur III (8)	Bodinayakanur IV (9)
Yields	479	446	435	424	700	667	678	1430	738

Conclusion 8 9 5 7 6 1 2 3 4

In these trials of different types of South India, it may be noted that all the types except *Anamalais erect* and *Anamalai flexuous* have yielded anything from 1½ to 3 times the yield of the Singampatti bulk. This indicated that selections from the smaller types of cardamom from other tracts such as Lower Pulneys, Travancore Cardamom Hills and Anamalais yield almost as highly as the best selections of the Singampatti Hills. These other types which

have yielded highly have globular or ovoid fruits which are the desirable features of the fruits The possibility of obtaining very high yielding selections from the smaller type of cardamom is also clearly indicated in the results of the above trials.

The yields obtained in the years 1951-54 in the best selections of the larger Singampatti type of cardamoms and selections (mostly smaller types) from other tracts are tabulated below to enable an easy comparison :—

Type of cardamom	Yield of green pods in 3 years 1951-54 expressed in pounds per acre	Yield expressed as a percentage on control (Singampatti bulk)
Varietal trials		
(1) Singampatti Ceylon	678.5	107.4
(2) Singampatti bulk (control)	631.9	100.0
(3) Anamalais flexuous	616.3	97.5
(4) Anamalais erect	560.8	95.1
(5) Munzerabad	991.7	157.0
(6) Pattiveranpatti	945.0	149.6
(7) Anamalais prostrate	960.5	152.0
(8) Bodinayakanur III	2036.0	322.6
(9) Bodinayakannur IV	1046.0	165.5
Yield trials		
Singampatti bulk (control) Selection No.	229.5	100.0
81	1113.5	485.2
71	1011.5	440.7
89	731.0	318.5
87	620.5	270.4
80	595.0	259.2
41	493.0	214.8
39	493.0	214.8
Singampatti Ceylon	246.5	107.4

It may be noted that the yields per acre as a whole is far better in the varietal trials than in the yield trials. This great difference in yields between the two trials may be due to the differences between the fertility of the two fields in which they were laid out. It should also be remembered here that the varietal trial was raised from seedlings whereas the yield trial was raised clonally.

Discussion

The study of the various ecogeographical races of cardamoms of South India, described in the first part of this paper, has brought out clearly the climatic, environmental, soil and other conditions required for the proper development of cardamoms. The results of these studies have to a very large extent confirmed the findings of Mayne (1942) with regard to these aspects of cardamom growing. According to the natural habitats of the two different ecotypes of cardamom, the larger and the smaller, it is seen that the larger type of cardamom is sufficiently productive only between 3000 and 4700 feet above sea level and in regions which hold good growth of evergreen forests. Below 3000 feet the productivity of this cardamom is seen to decline rapidly and below 2000 feet it is not productive at all.

The comparative study of the productivity or yield of the collection of single plants of the different local types of cardamom conducted at the Research Station in the Singampatti Hills, indicated that the smaller cardamoms can thrive well and be very productive even as

high as 4700 feet. The smaller type although light-sensitive, needing more shade and protection and require an ample soil moisture supply can be grown successfully and profitably down to elevations of even 2000 feet. The only cardamom suited to very low elevations is the local type *kanarensis* grown in North Kanara at the lower ends of valleys which may not be lower than about 1500 feet above sea level. In the Cardamom Hills of Travancore, Lower Pulneys, Mysore and Coorg, the other local types—*travancorica* and *oblongata* grow and are grown very successfully under partially deciduous forests and low annual rainfalls of 50 to 75 inches. It should not, however, be forgotten that the soil here is very rich and retentive of soil moisture. During the survey of the various cardamom growing tracts of South India, it was observed, as well as reported by cardamom growers that the larger type of cardamom yields better in Singampatti Hills and Anamalais whereas in tracts like Lower Pulneys, Papansam Hills and Cardamom Hills of Travancore, the smaller type does better than the larger. Cardamom growers may do well to bear in mind all these points while selecting the type of cardamom to be grown in a particular locality.

It has been the experience that in well laid out plantations, under favourable conditions the larger type of cardamom yields on an average anything from 50 lb. to 100 lb. of dry capsules per acre while the smaller cardamom may yield from 50 lb. to 85 lb. per acre. This refers to unselected bulk cardamom. However, the selections of the larger variety, made by the senior author, and tested under comparative yield trials yielded two to five times that of the unselected bulk. The trials of selections from the smaller types, however, have shown that some of them especially those from Bodinayakanur area (Cardamom Hills of Travancore) and Pattiveeranpatti (Lower Pulneys) have yielded one and a half to three times the yield of the bulk of the larger type. These results clearly indicate that there is vast scope for selection of high yielding plants from both the larger and smaller types, suitable for the various cardamom growing tracts.

Selections should be based on freedom of the clumps from diseases and pests, vigour of the clumps, production of large number of panicles with bold globular, ovate or oblong fruits closely and compactly packed on the panicles and large number of fruits on a single panicle.

With regard to the quality of the dried product, a larger, round and uniform produce having a good dark green colour always gets the highest price. Pods of a large round shape usually fetch a premium of seven to eight annas per pound. The small type of cardamom with the creeping panicle produces round or globular fruits of uniform size and shape giving a very attractive product. The larger type of cardamom in bulk gives different kinds of fruits of varying shapes and sizes from globular to longish fruits of nearly an inch in length resulting in a very non-uniform product. However, the dried product of the larger type retains the dark green colour which makes bleaching for the market easier.

A point of very great importance in cardamom production should be mentioned here. Cardamom is largely a self-sterile plant and monoclonal plantings of any considerable area are likely to prove to be unproductive. Under these circumstances it seems most advisable to raise mixed crops of different selections of the same type to ensure cross pollination and high productivity.

The senior author has described elsewhere (Abraham 1955) in detail methods of cardamom cultivation in general.

Summary

(1) The survey of the cardamom growing areas of South India has resulted in the collection of a vast fund of information on conditions under which cardamom types grow, the variability of elevation of the areas under cultivation of different types of cardamoms, nature of forests and the amount and distribution of annual rainfall as well as their relationships to the productivity of cardamom types.

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(2) Single plant selections of the types of cardamoms made during the survey were grown together at the Research Station in type trials where their productivity could be compared.

(3) Some of the smaller types with prostrate panicles collected from the Cardamom Hills of Travancore and the Lower Pulneys have yielded one and a half to three times the yield of the bulk of the larger type.

(4) Hundred and twenty single plant selections made by the senior author in 1942 from the indigenous cardamoms of the Singampatti Hills were available for study. The selections were made from three extensive plantations covering 1500 acres. Comparative yield trials of these selections spread over a period of thirteen years have resulted in the final selection of seven cultures yielding from two to five times the yield of unselected bulk.

(5) Various agricultural values of the different types of South Indian cardamoms are also discussed in detail.

ACKNOWLEDGMENT

The authors acknowledge with gratitude the great interest shown and encouragement given by Shri C. R. Seshadri, Oilseeds Specialist and Shri U. Narasing Rao, Horticulturist and Professor of Horticulture, Coimbatore, in the writing of this paper. Our thanks are due to Shri V. Gomathinayagam Pillai who was Cardamom Specialist in the absence of the senior author and to all the Assistants of the scheme for conducting part of the surveys and recording of some of the morphological features of cardamom types while they were in the Cardamom Scheme.

The authors' thanks are also due to the Indian Council of Agricultural Research whose financial aid made it possible to carry out this work and to Messrs. Bombay Burmah Trading Corporation, for the great interest shown in the work and for affording all facilities for work in their estates in the Singampatti Hills.

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